USGS
science for a changing world

April 26, 2001

The National Map: Invitation for Comments

Earlier this year, the U.S. Geological Survey's (USGS) Associate Director for Geography chartered a study to determine how to "... put truly current information into the hands of our customers ... in a cost effective way". Our vision is that by the year 2010, working with partners, we will provide the Nation with current, accurate, and nationally consistent basic spatial data, including digital data and derived topographic maps. The attached report from the study, *The National Map*, sketches an approach for achieving this vision.

Report Available for Review and Comment

This review invites partners, customers, and the public to review the report, and to improve it by providing comments on aspects (1) that are useful, (2) that need improvement, and (3) that should be reconsidered. Ideas about approaches to accomplish the goals of *The National Map* also are invited.

You may provide comments:

- By electronic mail to nationalmap@usgs.gov. Please provide comments in the body of the electronic mail message, or as an attachment in either Microsoft Word format or Rich Text Format.
- By regular mail to USGS – National Map Comments, 511 National Center, 12201 Sunrise Valley Drive, Reston, Virginia 20192. Please send one paper version of the comments and a softcopy version in Microsoft Word format or Rich Text Format on a 3.5-inch diskette.

Comments must be received by close-of-business on Friday, June 29, 2001.

The report is set up for double-sided reproduction, and so there are some blank pages. Some illustrations are in color.

Suggestions for Reviewers

The following suggestions are offered to help ensure that we understand your main points:

- **Organization of comments:** To ensure that we understand the part of the report about which your comments apply, consider organizing your comments by the sections of the report.
- **Types of comments:** We invite comments of the following types:
  - **Items that are useful:** Often when people comment on a document, they focus on items that should be changed. This approach leaves open the possibility that other people's comments may result in a change to an item that you thought was a good idea. Please help us by identifying items you support.

- **Items that need improvement:** For items for which the report has a useful idea, but takes the idea too far, not far enough, or in the wrong direction, please identify the item, your concern, and your thoughts of how it can be improved.
- **Items that need to be reconsidered:** For approaches that you consider to be an error, please identify the item, your concern, and why you believe the item is an error. Please provide your thoughts of other ways to approach or consider the item.
- **Items missed:** We invite ideas that could contribute to the goals of *The National Map* that are not included in the document.
- **Implementation ideas:** While the document primarily describes a concept, we invite ideas of how to move forward with implementation.

- **Parts of the report on which to comment:** We anticipate most comments will be for the pages numbered 5 through 16. If only part of the report interests you, please feel free to comment only on that part.
- **Additional materials:** If needed to help explain your comments, please feel free to provide other materials with your comments. (For example, several States and regions are working on plans that might cover similar topics through "I-team" efforts sponsored by the Federal Geographic Data Committee.) If the materials are available through the Internet, consider providing the web address to the materials instead of copies.
- **Restricted information:** Please DO NOT provide information or materials you consider to be confidential, proprietary, subject to privacy concerns, or otherwise restricted in access or use.
- **Tell us about you:** Please include your name, title, organization name, mailing address, electronic mail address, and telephone number. Anonymous comments will not be considered. We will use this information to identify sources of comments, and to contact you if we do not understand, or need more information about, a comment. If you are responding on behalf of a group, please identify the group. Please also provide information about how you use, build, or maintain spatial data or maps so that we better understand the context for your comments.

If there are parts of the report about which you have questions, and you would like more information before sending comments, please send the questions to us at nationalmap@usgs.gov.

What USGS Will Do with the Comments

USGS will use the comments to improve the report, to plan activities based on the report, and to review and improve ongoing USGS operations. We may share the comments with others not part of USGS in these activities.

Thank You for Your Help

Thank you in advance for your suggestions and criticisms. With your help, we can ensure that USGS activities contribute to building the basic spatial data America needs for the 21st century.

The National Map

Draft for Public Comment
April 26, 2001

The use of trade, product, industry, or firm names in this report is for descriptive purposes only and does not constitute an endorsement by the U.S. Government.

Preface

This report is the result of a short, intensive study chartered by the U.S. Geological Survey's (USGS) Associate Director for Geography to determine how to address evolving needs for current basic spatial data. Our vision is that by the year 2010, working with partners, we will provide the Nation with current, accurate, and nationally consistent basic spatial data, including digital data and derived topographic maps, and deliver spatial information that is not more than seven days old.

Questions considered during the study included: what form should USGS maps and spatial data take, how can lag time between changes on the ground and corresponding updates in data and on maps be reduced, and how should the USGS create and maintain these data and maps?

Key individuals familiar with the development and use of spatial data provided information during the study. The individuals were from (1) the leadership and scientists of the USGS; (2) associations of professionals and organizations, including the American Society for Photogrammetry and Remote Sensing, Association of American State Geologists, National States Geographic Information Council, Open GIS Consortium, Inc., and University Consortium for Geographic Information Science; (3) Federal agencies, including the Bureau of the Census, Federal Emergency Management Agency, National Imagery and Mapping Agency, U.S. Environmental Protection Agency, and U.S. Forest Service; (4) State agencies from Kentucky and Texas; (5) regional agencies, including the Denver Regional Council of Governments and the MetroGIS activity sponsored by the Metropolitan Council of the Minneapolis-St. Paul, Minnesota, area; and (6) private companies, including DeLorme, Dewberry & Davis LLC, ESRI, GeoDigital Mapping, Inc., Intermap Technologies, Inc., Microsoft Corporation, Navigation Technologies (NAVTECH), Nova Blue Inc., and Space Imaging, Inc. All participants graciously made time in their busy schedules on very short notice. The USGS very much appreciates their willingness to provide valuable insights. (Please note, however, that the USGS conducted the study, and that the report may not represent the views of the persons interviewed, or their organizations.) A number of documents, listed in the References section, also were reviewed.

To meet needs and take advantage of technological and other developments, the study recommended the development of *The National Map*. *The National Map* is proposed as a database of basic spatial data that will provide a starting point for users to extend and enhance, and to which users could tie additional data, to meet their business needs. USGS will provide the leadership needed to develop and continually maintain these data through partnerships among Federal, State, local, and tribal governments, the private sector, other organizations, and volunteers.

This report sketches an initial concept and way of moving forward with *The National Map*. USGS invites partners, customers, and the public to review the report, and comment on aspects that they find useful, that need improvement, and that should be reconsidered. Ideas about approaches to accomplish the goals of *The National Map* also are invited. Comments can be sent by electronic mail to: nationalmap@usgs.gov

Contents

Choices About the Future – Being Made Today

The National Map will underpin mission activities of Federal agencies, as well as other public and private organizations. The proposed continually maintained, nationally consistent set of basic spatial data will provide a starting point and organized means for integrating, sharing, and using spatial data easily, consistently, and quickly.

The following vignettes, set in the year 2010, offer ideas of the consequences of no action, and of how *The National Map* could benefit the Nation.

Vignette 1: Status Quo

FAIRVIEW, August 15, 2010 – It had been a long fire season, and it wasn't going to let up soon. Local, State, and Federal firefighting crews were being augmented by military units.

The commander of a newly arrived unit entered the command post. "Where do you want us?" he asked the Ops Chief.

"Come here and I'll show you," replied the Ops Chief. On a table were maps updated and annotated by hand using a rainbow of colored pencils. Stacked around these maps were USGS and other maps, aerial and satellite photos, and plots from computer files. Even a few tourist maps peeked from the pile, and the commander swore one looked like the map on the placemat from a local diner. "What's this?" he asked.

"We use the maps to plan fire lines," the Planning Section Chief said half-apologetically. "We get whatever base maps are available. They're often not current, and we update them with whatever information we can get. This probably is the first time most of this information has been pulled together. The information often doesn't fit well, but we do the best we can in the time we have."

"Isn't there anything better available?" asked the commander. The Planning Section Chief noted that, as a result of local interest and resources, there were good integrated digital base maps available for limited areas. "They're great to use, but they're often not available, or don't contain the topographic information we need" he noted. "And where they are available, they usually stop at a county or forest boundary. Unfortunately, fires aren't too picky about crossing boundaries. There are less detailed satellite and other data that cover larger areas. They're great for getting an overall view, but they don't help much in the field. As for base maps for tactical firefighting, USGS topographic maps are available, but they're often out of date. No one pulls existing data together, fills in the gaps, and keeps the information current, so we make do."

The Ops Chief pointed to an area on the map. "We need your people to establish a fire break here. We're trying to protect some homes further up the mountain." "Where are the buildings?" the commander asked. "I don't see them on the map." "They're out there," the Planning Section Chief replied. "But we don't know exactly where, and so we can't plot them on the map."

"Hell of a way to fight a fire," the commander muttered as he left the command post.

Vignette 2: Common Action Enabled Through a Common Set of Basic Spatial Data

MIDWAY, July 4, 2010 – After years of cleanup efforts, the river was open to swimmers. On a hot, muggy Fourth of July, people were drawn to the river–swimming, tubing, boating, and fishing. They had no idea of how exciting their vacations were about to become.

Upriver, a containment pond had given way, and thousands of gallons of caustic sediment were pouring into the river. The skeleton staff at the plant alerted the emergency spill center, which swung into action.

Their first priority was public safety and health. Using *The National Map* developed and maintained by USGS and other organizations, they located on recent digital aerial photos and river and lake data the place where the spill entered the river, and identified the area and facilities downstream that the spill was most likely to affect. Water utilities with intakes in the area were ordered to stop pumping. Media broadcast warnings to stay clear of the contaminated water; however, officials were concerned that people on the river might not receive the warning in time. In a flash of inspiration, they remembered that personal

electronic devices had been equipped with Global Positioning System receivers for years. Using *The National Map* to outline an area that included the river and land within 100 yards of the shore, they identified all the devices in the area and sent them a simple message – "HAZARDOUS SPILL – LEAVE THE RIVER NOW." People headed for shore as the river came alive with the chirping of cell phones, pagers, and personal digital assistants.

The center also warned Federal and State natural resource and environmental agencies of the spill. The agencies, with partners from industry and non-governmental organizations, had been linking information about water quantity and quality, the shape and makeup of the riverbed, and aquatic plants and animals, to *The National Map* for years. The agencies used these spatially referenced data to plan actions to minimize damage and start clean-up operations. "At least it won't get much worse," said one chemist after using the data to determine that the spill was unlikely to interact with other naturally occurring chemicals in the river. Using *The National Map*, scientists pinpointed wetlands and alerted field personnel to place barriers to protect this productive habitat.

Having issued the warning, the center concentrated on predicting the likely extent of the spill. By analyzing real-time river flow information, elevation and land cover data, and weather forecasts, they estimated the rate of the spread of the spill, and produced maps showing impacted areas and access routes for remediation teams. "How about that," one official exclaimed, "we might get ahead of the spill before it reaches the Mississippi."

Executive Summary: The National Map

The report proposes *The National Map*, a database of continually maintained basic spatial data for the United States and its territories that would serve as the Nation's topographic map for the 21st century. Improvements would include greatly increased attention to keeping the information current, seamless national digital data coverage to avoid problems now caused by map boundaries, higher resolution and positional accuracy where needed to better support field operations, better data integration to improve the usefulness of the data, and increased reliance on partnerships and commercially available data.

Governments depend on a common set of basic information that locates and describes the Earth's surface and features as a tool for land and natural resource management, economic and community development, and health and safety services. Federal functions ranging from land management to emergency management and defense to environmental protection depend on this information. Private industry, nongovernmental organizations, and citizens also use these geographic data. Spatial information underpins an increasingly large part of the Nation's economy.

The National Map will serve as a foundation for integrating, sharing, and using spatial data easily and consistently, and provide a new approach to provide current information, and retain and improve other valued characteristics such as positional accuracy and completeness.

By 2010, under the leadership of the U.S. Geological Survey (USGS), *The National Map* will provide data and operational capabilities that include:

- High-resolution digital orthorectified imagery. Imagery will provide some of the feature information content now symbolized on topographic maps.
- High-resolution surface elevation data.
- Vector data for hydrography, transportation (for example, roads, railways, and waterways), structures, and boundaries of government units and publicly owned lands.
- Geographic names for physical and cultural features.
- Land characterization data classifying land cover types.

The USGS will continue to provide a standard set of paper topographic maps and digital data derived from *The National Map*. Customers also will be able to create their own maps by defining a geographic area of interest, selecting unique combinations of data, and printing their maps at home or at kiosks.

Changes to *The National Map* will be captured in near real-time, rather than through cyclical inspection and revision. Currentness will be measured in days and months. The ultimate goal is that changes will be recorded within seven days of a change on the

landscape. Features will be represented in their entirety and consistently classified, enabling users to extract data for geographic areas such as counties or watersheds, and allowing improved computer analysis of the information. Data resolution and completeness will vary depending on geographic area and need. Positional accuracy will be sufficient to align features from different data themes.

The initial version of *The National Map* will be based primarily on existing available data. As the initial version is improved, emphasis will shift to maintaining data currentness through continual update. Potential data sources include State and local governments, private industry, and trained and certified local volunteers.

The National Map will be accessible continuously through the Internet. The concept calls for data to be in the public domain, which sometimes may require the purchase of unlimited distribution rights for data from commercial sources. However, emerging technologies that employ remote data processing and analysis capabilities may enable users to apply data without retaining a copy, and make possible inclusion of licensed data in *The National Map* when unlimited distribution rights are not available.

Users will be able to combine data from *The National Map* with spatial information available from other organizations, such as cadastral information from the Bureau of Land Management and demographic data from the Bureau of the Census. *The National Map* will be a foundation to which organizations spatially can reference their information, such as land use data, school district boundaries, or wildlife counts.

The success of *The National Map* will depend on the participation of many organizations. USGS will lead the development and maintenance of *The National Map* by being: (1) guarantor of national data completeness, consistency, and accuracy; (2) organizer responsible for awareness, availability, and utility of *The National Map*; (3) catalyst and collaborator for creating and stimulating partnerships; (4) integrator of data from other participants; and (5) owner and data producer when no other sources for needed data exist.

USGS will seek partnerships and business arrangements with other organizations to develop and operate *The National Map*. USGS staff will be located across the Nation to work directly with partner Federal, State, or other public organizations, private industry, and universities. Federal agencies would identify needs, and develop and execute plans for collaborative data development and maintenance. The role of USGS in these relationships could range from being the organizer of collaboration to working with other agencies to support the inclusion of their data in *The National Map*. State and regional consortia would coordinate area-specific spatial data development to respond to local issues and, where interests align, maintain and operate *The National Map* for their area. Private organizations would provide analysis and visualization tools, develop open technology and processing standards, and provide data under contract or license. USGS will work with university faculty on relevant research topics. USGS will encourage volunteers to help detect change and maintain *The National Map*.

The next steps include conducting a review of the concept to identify key advantages and deficiencies, aligning USGS activities with the concept, and forging relationships with organizations interested in the vision.

The National Map

The Needs of the Federal Government, and the Nation, for a Common Set of Basic Spatial Data

Governments are inherently geographic. All governments need spatial data that locate and classify lands and waters, describe the distribution of peoples, economic activities, infrastructure, and natural resources, and document the products of their domains. The National Academy of Public Administration (1998) identified twelve broad Federal functions, ranging from economic and community development to emergency management and defense to environmental protection, that require spatial data. The report summarized the Federal Government's role in spatial data functions as "one in which government is expected to help ensure public safety, manage the public lands for multiple uses, preserve the nation's resources for future generations, and help meet the basic needs of an expanding economy."

Spatial data required by the Federal Government also are used by State, regional, local, and tribal governments, private industry, nongovernmental organizations, and individual citizens. Paper maps and digital forms of spatial data developed to meet Federal needs underpin an increasingly large segment of the Nation's economy. The economic multiplier of freely available spatial data is significant. A 1997 National Research Council report concluded that

> Spatial data have helped form a foundation for commercial enterprises, such as delivery services, and have also led to enhanced market analyses. At the same time, the use of spatial data has reduced costs and increased efficiencies in a wide variety of areas where it is necessary to manage large networks of geographically dispersed facilities, most notably in the utility industries, transportation, and local governments. Policies and practices of open and affordable access to spatial data have contributed to U.S. leadership in the world markets of spatial data technologies and applications.

The USGS's Role in Meeting These Needs

A common set of basic information that locates and describes the Earth's surface and features is the starting point for most geographic activities. Many Federal agencies need such current, accurate, and consistent basic spatial data for their mission activities. *The National Map* would be a database of continually maintained basic spatial data for the United States and its territories, and would serve as the Nation's topographic map for the 21st century. It would provide a base that Federal agencies and others could extend and enhance, and to which they could tie additional data they need to accomplish their

missions. It would contain sufficient detail to support national, regional, and field activities. Guaranteed availability of *The National Map* would allow Federal agencies to concentrate on data unique to their mission needs, and to avoid expending resources to find, develop, and integrate basic spatial data each time they are needed. Within USGS, *The National Map* would serve as the organizing mechanism for spatially referenced scientific data by forming the core of an enterprise-wide geographic information system.

Most Federal agencies do not have responsibilities to develop or maintain these data. An exception is the U.S. Geological Survey (USGS), which has a mission mandate to fulfill such a role. Many Federal agencies and other organizations rely on spatial data provided by the USGS as a common foundation for their activities. The most widely known form of this information is the USGS primary series of topographic maps[1], which are a complete and consistent picture of our Nation's lands. The maps, complemented by digital forms of the mapped information and aerial and satellite imagery, support numerous Federal activities, including saving lives and property in natural disasters, aiding other bureaus of the Department of the Interior in carrying out their stewardship and regulatory responsibilities, and providing a cornerstone for other USGS science programs. These spatial data also have been used widely by State, regional, and local governments, the private sector, and other organizations. Citizens use the maps in educational, recreational, environmental, and conservation activities, and to explore and understand natural resource issues. The maps help people connect with the Earth through the power of place and geography.

The development and maintenance of basic spatial data for the Nation has and will continue to require a significant national commitment and engineering effort. To give a sense of the scope of the effort, the USGS primary topographic map series includes more than 55,000 unique map sheets, and 220,000 digital orthorectified images[2], to cover the United States. While one form of these spatial data, the paper map, once was sufficient, Federal needs evolved over the last 20 years with developments in computer technology. USGS responded to these changing needs by providing basic spatial data in a number of digital forms in addition to the paper map form. While these maps and related digital data are considered by many to be a national treasure, they rapidly are becoming less valuable as they age. For example, the average age of the primary topographic series maps is 23 years. In many cases, much change has occurred on the landscape and the map no longer provides an accurate portrayal. Complementary digital images often are more current; however, maintaining the currentness of the data provided by USGS, while

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[1] The primary topographic map series subdivides the United States into four-sided figures called quadrangles, which are bounded by lines of latitude and longitude. Topographic maps present the horizontal and vertical positions of represented features. The maps show relief (elevations and depressions), water features, roads and railroads, structures, boundaries, names, and other information. The most widely known map in the series is the 7½-minute quadrangle, most of which are published at a map scale of 1:24,000 (one inch on the map represents 2,000 feet (24,000 inches) on the ground). For Alaska, most quadrangles are 15 minutes in latitude, and from 20 to 36 minutes in longitude, and are published at a scale of 1:63,360 (one inch on the map represents one mile (63,360 inches) on the ground).

[2] An orthorectified image is an aerial photograph or satellite image from which displacements caused by terrain and other factors have been removed. The resulting image has the image characteristics of a photograph and the geometric qualities of a map.

retaining other valued characteristics such as positional accuracy and completeness, is a challenge, especially for areas of rapid development.

As the Nation's largest civilian mapping agency, USGS has the responsibility to organize and lead partnerships and activities that provide basic spatial data needed by Federal agencies and other organizations. Clearly a new approach is needed to keep up with rapid changes on the landscape, and to provide current, accurate, consistent, timely, and useful basic spatial data.

Changing Needs for Spatial Data, and Opportunities for Meeting These Needs

The rapid pace of improvements in digital technologies, and plunging unit costs for these technologies, are changing the way information is made available and used. The use of spatial data has been affected radically by these trends. Computerized capabilities to use spatial data, such as geographic information systems, and to acquire the position of features and events, such as the Global Positioning System, are changing the spatial data needs of organizations and individuals, and are providing new opportunities to meet these needs.

Major current and developing spatial data needs, and the implications of new capabilities, include:

- *Data:* There continues to be an unmet need for a common set of basic spatial data. For some places, much data are available; for others, there is very little data. These data must be current and useful for any arbitrarily defined geographic area. Both digital and paper forms of basic spatial data are needed.
- *Technology:* Technology will continue to evolve, and will provide new ways to collect, maintain, access, and use basic spatial data.
- *Partnerships:* Common needs and interests offer opportunities for partnerships to collect, maintain, access, and use basic spatial data among Federal agencies, and with other public organizations, notably State and regional organizations. Private sector investments in capabilities to collect, maintain, access, and use basic spatial data, and in the development and maintenance of data, provide opportunities to meet Federal needs. Volunteers may be an untapped source of information needed to maintain basic spatial data.
- *Federal leadership:* Federal leadership and commitment are needed to ensure that basic spatial data are available to support Federal agencies in accomplishing their missions. The USGS has the mission to lead the development and maintenance of this common set of basic spatial data, although a new approach is needed. USGS leadership and participation in current interagency data development programs, as well as in activities of the Federal Geographic Data Committee, provide starting points and contexts for developing and maintaining basic spatial data.

Appendix 1 contains a summary of these changing needs and opportunities.

The National Map

The proposal for *The National Map* sketches the initial concept and way of moving forward to meet needs for basic spatial data. The goal of *The National Map* is to provide, by 2010, a common set of basic spatial data and operational capabilities with the following characteristics:

Information Content

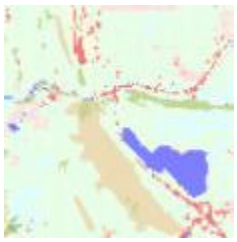
The National Map will consist of several themes of spatial data, the initial set of which are:

High-resolution digital orthorectified imagery. An orthorectified image is an aerial photograph or satellite image from which displacements caused by terrain relief and sensor tilt have been removed. The result combines the image characteristics of a photograph with the geometric qualities of a map. Images will be collected using the most efficient and effective combination of aircraft- and satellite-based capabilities.

High-resolution surface elevation data. At a minimum, these data will have sufficient detail to yield contours of resolutions and accuracies for maps of the primary topographic map series, to develop high-resolution and highly accurate orthorectified imagery, and, in areas of subtle relief variation such as flood plains and coastal areas, to support hydrographic and other modeling. *(Data courtesy of Intermap Technologies, Inc.)*

Vector data, encoded using points, lines, and areas, for the themes of hydrography, transportation (especially roads, but also including railroads and waterways), structures, boundaries of governmental units, and administrative boundaries of publicly owned lands. These data will have minimal associated descriptive information; in most cases, the information content will include simple classification information (for example, “stream/river” and “lake/pond”), and a geographic name. Feature-based linear referencing systems required by Federal organizations to link their mission data to *The National Map* also will be included. Examples of these systems include reach codes for hydrography data that support operations of the U.S. Environmental Protection Agency, U.S. Forest Service, and USGS, and street addresses that support operations of the Bureau of the Census.

Geographic names. These names include those for physical and cultural geographic features needed to support the U.S. Board on Geographic Names.



Land characterization information. These data characterize the surface cover by classifying seasonal land cover types. They are developed from a combination of aircraft and satellite data.

Data Characteristics

The National Map data will have the following characteristics:

- Currentness based on changes in the landscape instead of cyclical inspection cycles now in use, and measured in days and months, not years. *The National Map* currentness goal is that change be incorporated within seven days of an event on the landscape. The most likely candidate themes to achieve this goal are imagery and transportation, especially roads.
- Seamlessness, in which features are captured in their entirety, and not interrupted by artifacts such as map edges.
- Consistent classification, in which the type of feature, such as "road" and "lake/pond", is identified the same way throughout the Nation.
- Variable resolution and completeness. For example, image resolution, or pixel size, may vary among images of urban, rural, and wilderness areas. The resolution of elevation data may be finer in floodplain, coastal, and other areas of low relief than for areas of high relief.
- Consistency and integration among data themes, so that related content, such as elevation and hydrography data, registers and matches.
- Variable positional accuracy of spatial data. Positions will be based on locations on the ground, and will not have offsets, generalizations, or other adjustments made to improve legibility on paper maps. The coordinates for spatial data will be based on a common referencing system. The minimum positional accuracy is that of the current primary topographic map series and related spatial data.

A means of tracking changes on the landscape through time also is required.

For many areas, *The National Map* will contain data that surpass standards for these characteristics for the current primary topographic map series and related digital spatial data.

Metadata will document the content of *The National Map*, and variations among data characteristics.

Figure 1 illustrates the importance of proposed National Map data characteristics. Seamless and consistently classified data allow similar views to be generated for any area; consistent and integrated data ensure that, when combined, the data register well; and currentness ensures that the data accurately represent the ground. These qualities are important for maps and other displays of data. They also are essential to ensure accurate results from automated analyses of the data.

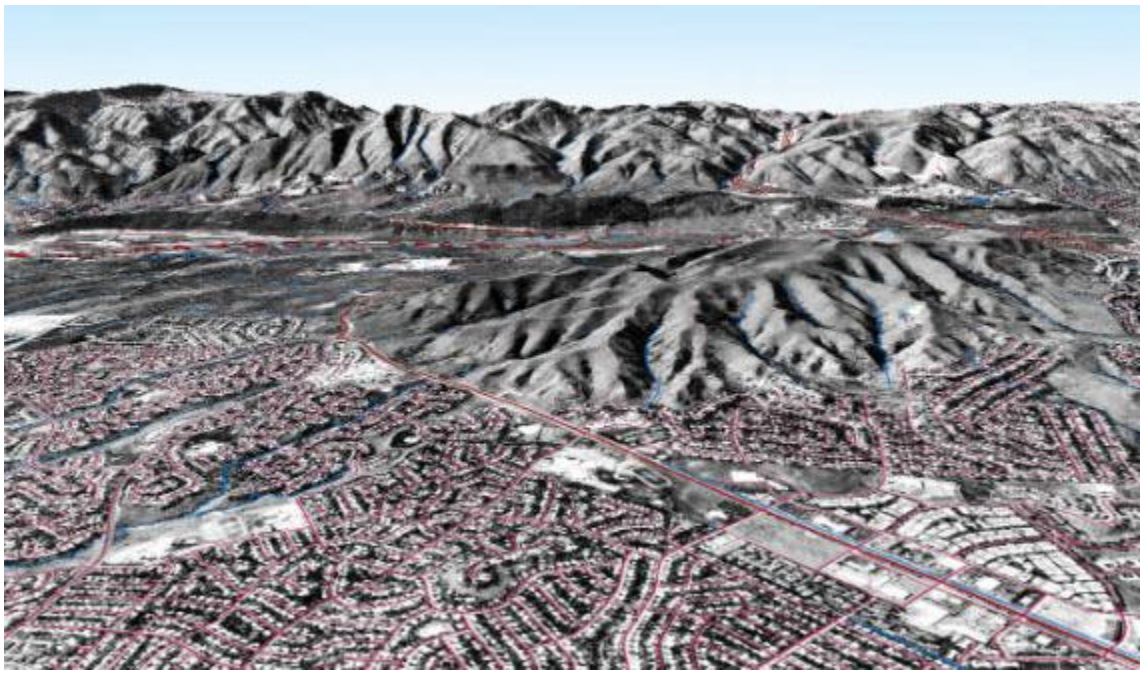


Figure 1. Computer-generated image for an area west of Denver from data such as those proposed for *The National Map*. In the figure, a shaded three-dimensional perspective view is generated from elevation data, and orthorectified image, transportation (roads in red), and hydrography (in blue) data are draped over the view.

Development, Maintenance, and Operations

The initial version of *The National Map* largely will be based on available data. Sources of data will include current holdings of the USGS and other participating organizations. When needed, new data will be obtained primarily through contracts with the private sector, and purchases of data available in the marketplace. The initial version will not achieve all the characteristics described in the previous section, but data will be improved and replaced over the next decade to address deficiencies and to achieve and maintain currentness.

As the initial version is improved, emphasis will shift to maintaining data currentness through continual update. When a change on the landscape occurs, database updates will be made through transactions, in which only the needed changes to the data will be processed. These updated data will be made available immediately. The processing of transactions will require ensuring the integrity of the resulting change with similar data for surrounding areas (for example, making sure new roads fit into the existing road network), and with related data from other themes in the same area (for example, making sure changes in hydrography data match the elevation data).

Critical to success is a robust means of knowing about changes when they occur, and receiving spatial data that faithfully represent the changes for inclusion in *The National Map*. The ideal sources for information about a change, and for new data that represent the change, are those close to the change, such as local governments, local offices of other public and private organizations, or trained and certified local volunteers. The

preferred approach would be for these organizations or persons to "push" updates to *The National Map* when changes occur on the landscape. Another approach is for public and private sector organizations that have reporting relationships with local organizations or individuals to act as intermediaries for providing updates to *The National Map*. A third approach would be for USGS to detect changes from imagery or from notifications of changes provided by others, and directly acquiring the data needed to update *The National Map*. The approach used for an area will depend on the relative costs of available approaches.

Computing and telecommunications technologies will allow a number of options for organizing the data. *The National Map* may develop as a networked, distributed collection of databases, operated by public or private sector organizations, that agree to provide basic spatial data that meet common criteria and levels of service. While the data may be distributed among many sites, the data in *The National Map* will appear seamless to a user.

To continue to be relevant, it is important that *The National Map* be developed and improved in response to users' needs as well as changing technical and organizational requirements. There must be a means to obtain feedback from users, and to respond to reported deficiencies and changing needs.

Access and Use

The National Map will provide around-the-clock access through the Internet to basic spatial data, based on user-specified combinations of data and geographic area of coverage. Views of the data and transfers of reasonable amounts of data through the Internet would be provided at no cost. Access to large volumes of data may require a fee to pay for media and other distribution costs.

To allow these data to flow unimpeded and be of maximum flexibility for Federal agencies and their cooperators, data in *The National Map* will be in the public domain, and data developed with Federal funds are in the public domain. In cases where rights to data are held by private organizations, the purchase of unlimited distribution rights to commercially available data may be required. However, new remote processing technologies that allow the use of data without actual possession of the data may allow needs to be met as readily with licensed data as with public domain data. The success of these technologies and negotiation of appropriate licenses may provide alternatives to the requirement that all data in *The National Map* be in the public domain.

The National Map also will provide means of accessing and using other data from Federal agencies and other organizations, using open technology and processing methods such as those being developed through the Open GIS Consortium. One method will be use of *The National Map* as a reference tool to access additional attribute information, such as detailed USGS scientific data. Another method will be the combination of displays of *National Map* data with themes available from other organizations, such as geodetic control and bathymetry data from the National Oceanic and Atmospheric Administration, cadastral information from the Bureau of Land Management and State agencies, soils data from the Natural Resources Conservation Service, or demographic data from the Bureau of the Census. Similarly, data from local agencies, such as zoning,

school, or watershed protection data, could be displayed in combination with data from *The National Map*. In addition, *The National Map* could provide access to more detailed data or value-added services available for a fee from public or private organizations.

The USGS also will provide a standardized set of paper topographic maps and digital data created from *The National Map*. This view of *The National Map* will be the continuation of the USGS primary topographic map series and complementary digital data. Imagery may carry some of the information content now encoded with map symbols; for example, an image might substitute for symbols used to portray constructed features. Customers will have the flexibility to define map boundaries and to select different combinations of data to produce maps that best suit their needs. In addition, public and private organizations may develop kiosks that provide customized maps on demand through a distributed retail network (for example, at gas stations, convenience stores, recreational stores, coffee shops, bookstores, libraries, and post offices).

Organizational Issues and Strategies

The success of *The National Map* will depend on the participation and support of many organizations. To ensure success, USGS must lead, develop, and sustain mutually beneficial relationships with other organizations. These issues will be among the most challenging to be addressed in developing and maintaining *The National Map*.

Roles of the USGS

USGS will provide the national leadership to develop and maintain *The National Map*. This leadership includes being: (1) guarantor of national data completeness, consistency, and accuracy; (2) organizer responsible for awareness, availability, and utility of *The National Map*; (3) catalyst and collaborator for creating and stimulating partnerships; (4) integrator of data from other participants; and (5) owner and data producer when no other source for needed data exist.

Within USGS, the responsibility for *The National Map* will be vested in the Associate Director for Geography. Program priorities and commitments will be aligned with financial and personnel resources to accomplish this responsibility. Priorities for the development and operation of *The National Map* will be reviewed and endorsed annually to update the long-term strategy, to define intermediate goals, and to establish an annual operating plan. Standards for currentness and strategies for maintenance and operations will be reviewed annually to consider new geographic, societal, and programmatic priorities (for example, regional patterns of wildland fire, coastal erosion activity, disease diffusion trends, and other Federal requirements). Because the USGS will depend on partners to develop and operate *The National Map*, program staff will concentrate on agreements needed to meet the goals of the program.

Because the ability to meet Federal needs is central to the success of *The National Map*, USGS will provide liaison staff to Federal agencies to understand their evolving needs,

and to identify opportunities to work with agencies that produce spatial data that could contribute to *National Map* maintenance. For similar reasons, substantial numbers of employees will be located in area maintenance offices to work with other USGS offices, partner organizations, and a volunteer workforce. These offices will analyze requirements, develop partnerships, and identify data for *The National Map*, and will provide data acquisition, evaluation, integration, and applications expertise to partners and users. When fully implemented, these offices will be responsible for ensuring that *The National Map* meets needs of Federal agencies in their area. USGS also will encourage rotational assignments of staff among USGS offices, and in university and private industry settings.

In addition to the area maintenance offices, USGS centers with responsibilities for *The National Map* will provide primary management, technical, and administrative support, including:

- Providing leadership by monitoring and responding to national trends in spatial data development and use, developing and managing standards, and providing independent technical expertise in the application of spatial technologies and data.
- Providing core production and workforce to provide the technical underpinning to *The National Map*.
- For times when a surge capability is needed, such as during hazards and disaster response and recovery operations, supporting data "swat teams" to meet immediate needs for geographic information and applications.
- Addressing needs for cartographic, geographic information, and general information science research.
- Staffing systems development, administration, and support activities.
- Providing product generation operations, including those needed for standard USGS digital and paper map products.

To date, USGS has organized, led, and participated in interagency data development activities to pool resources and make needed data available to Federal agencies and others. For example, USGS leveraged Federal and State resources over the last decade to provide coverage of digital orthorectified imagery through the National Digital Orthophoto Program; first-time coverage nearly is complete for 49 States. Similarly, USGS worked with the U.S. Environmental Protection Agency to provide initial national coverage of the National Hydrography Dataset, and is working with Department of the Interior bureaus, the U.S. Forest Service, U.S. Environmental Protection Agency, and States to develop more detailed data. Through the National Digital Elevation Program, USGS leads a consortium of Federal and State organizations that require elevation data. Through *The National Atlas of the United States of America*, USGS leads partnerships to integrate national datasets and provide a portal to thousands of Internet sites across the country. Partnerships also exist for land characterization data and for geographic names. USGS participates on State geographic information development activities, and provides leadership for themes of data in the Federal Geographic Data Committee. This experience will guide new partnerships needed to develop *The National Map*.

In order to realize the full vision of *The National Map*, it may be useful to investigate a legislative initiative, patterned on the National Cooperative Geologic Mapping Act, which could clarify Federal responsibilities and support partnerships with State, regional, and academic organizations. Comment on this issue will be sought as implementation progresses.

Roles of Partners

Partnerships are the key to the success of *The National Map*. To provide overall guidance, a proposed Federal advisory committee, consisting of representatives from the USGS and other Federal organizations, participating State and regional organizations, the private sector, and academia, will make recommendations on evolving requirements, approaches to data maintenance and processing, systems and technology development and implementation, and skill enhancements that contribute to *The National Map*.

Federal partners. The USGS will work with other Federal agencies to identify needs, and to develop and execute plans for collaborative data development and maintenance. The role of the USGS in these relationships could range from being the organizer of collaboration to working with Federal agencies to support the inclusion of their data in *The National Map*. In addition to strengthened cooperation within the USGS for hydrography and elevation data, examples of potential partners among Federal agencies include bureaus in the Department of the Interior and the U.S. Forest Service (basic data needed to manage Federal lands), Bureau of the Census (roads and structures), U.S. Environmental Protection Agency (hydrography and land characterization), Federal Emergency Management Agency (elevation), the Department of Agriculture (imagery), and the National Imagery and Mapping Agency (data required for national defense). Other potential partners include the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, Department of Housing and Urban Development, Federal Communications Commission, Federal Aviation Administration, and the Centers for Disease Control and Prevention.

State and regional partners. USGS will strengthen its coordination with State and regional partners to develop and maintain *The National Map*, and to ensure its usefulness and accuracy. When partnership arrangements can contribute to *The National Map* and meet Federal needs, USGS will participate in State and regional consortia that coordinate area-specific spatial data development to respond to local issues. USGS participation will include providing national and multistate program perspectives, coordination leadership as appropriate, and guidance and expertise on data development and maintenance strategies. Participation may include developing strategies for data collection and maintenance, and pooling funding, expertise, and other resources. Area maintenance offices will develop business relationships needed to receive reports of events (for example, utility hookups, building permits, and road construction) that identify changes and trigger data maintenance efforts. Building on successes such as that of the Texas Natural Resources Information System, USGS will encourage similar comprehensive State mapping capabilities. Where State and regional organizations share the goals of *The National Map*, they may develop, maintain, and operate *The National* Map for their geographic area. In these cases, USGS will support their activities through cooperative agreements.

Private industry partners. USGS will partner with private organizations that develop and supply geographic information analysis and visualization tools for broad public access, and that develop open technology and processing standards needed to take advantage of new computing and telecommunications technologies. USGS also will buy data for *The National Map* from the private sector when the data and related licensing provisions support Federal use of the data. These procurements could be single purchases, or subscriptions to update services. When data are not available for an area, USGS will contract with the private sector for data production and processing. For the derivation of products from *The National Map* beyond standard Internet-based displays and paper topographic maps, USGS will rely on the private sector to provide value-added output capabilities for public access, including demands for customized paper maps.

Academic partners. On cartographic, geographic information, and general information science topics relevant to *The National Map*, USGS will work with university faculty by supporting research and through rotational assignments.

Partnerships with the public. Taking advantage of the anticipated widespread availability of Global Positioning System capabilities in personal electronic devices, USGS will certify and encourage the participation of organizations such as the Appalachian Trail Club and scouting organizations, and private citizens, to serve as a volunteer force for maintaining and validating *The National Map*. These persons will be trained through a virtual "volunteer academy" and interact regularly with area maintenance offices. To support this large, semi-public activity, USGS will partner with private industry to ensure the widespread availability of low cost techniques that integrate Global Positioning System, wireless and broadband communications, high-resolution displays, and mass data storage technology.

Needed Research and Development

The near-term technical functions needed to accomplish this vision will be met using commercially available capabilities. Development will be required to integrate these capabilities, and to configure them to aid development and maintenance of *The National Map*.

To satisfy mid- and long-term goals, work is needed in applied cartographic, geographic information, and general information science research. These investigations will be focused on needs that must be met in the next two-to-five years, and will be pursued with partners from academia and private industry. Appendix 2 contains a list of topics that require investigation.

Next Steps

The USGS plans to conduct the following activities to refine and begin to implement *The National Map*:

- Conduct a wider review of the concept to identify key advantages and deficiencies.
    - Sponsor a review of the concept through sessions at professional meetings and written comments.

- Develop timelines and estimates of resources required to achieve the goals for *The National Map*.
- Identify topics that require more formal study.
- Revise and add clarity to the concept based on comments, and results of test, demonstration, and implementation activities.
- Develop a business model and funding plan for implementing *The National Map*.

- Align USGS activities with the vision.
  - Review current and planned program activities to identify their fit with *The National Map*, and identify needed changes to the programs.
  - Identify and make needed changes in business practices.
  - Identify characteristics of the workforce required to implement the concept, and address deficiencies.
  - Evaluate data holdings to understand their currentness, and to identify in more detail the information content to be retained in *The National Map*.
  - On a pilot basis, expand selected current state liaison activities to assess the potential contributions of area maintenance offices.
  - As implementation progresses, identify needs for a legislative initiative.
- Forge relationships with organizations interested in the vision.
  - Identify organizations that currently employ an approach similar to that proposed, and work with them to identify key steps required to implement the concept.
  - Evaluate the characteristics of other organizations' holdings of spatial data, and techniques for collecting and maintaining these data, to understand what their value may be to *The National Map*.
  - Work with key Federal agencies to understand their needs for spatial data, and how their plans will coincide with implementation activities for *The National Map*.
  - Work with interested State and regional agencies to test and demonstrate aspects of the concept, and to assess their interest in participating in *The National Map*.
  - Identify priority research topics, and opportunities to work with the academic and private sectors to undertake these investigations.
  - Identify priority technology developments needed to implement *The National Map*, and opportunities to work with standards and other organizations to understand and influence these developments.
  - Make an initial assessment of how volunteers can best aid the development of *The National Map*, and identify and work with interested volunteer groups.

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Glossary

accuracy – the closeness of observations to true values or values accepted to be true. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

area – a generic term for a bounded, continuous, two-dimensional object that may or may not include its boundary.

attribute – a defined characteristic of a feature. For example, “name” is an attribute for a feature “road”.

attribute value – a specific quality or quantity assigned to an attribute for an occurrence of a feature. For example, “Spring Street” is the attribute value for the attribute “name” for an occurrence of the feature “road”.

bathymetry – the science of determining depths of oceanic or other deep waters.

cadastral information – the geographic extent of the past, current, and future rights and interests in real property, including the spatial data needed to describe that geographic extent.

completeness – the relationship between the objects represented and the abstract universe of all such objects; in particular, the exhaustiveness of a set of features.

contour – an imaginary line on the ground, all points of which are at the same elevation.

coordinates – a set of numeric quantities that describe the location of a point in a geographic reference system.

database – a collection of information related by a common fact or purpose.

datum – any quantity, or set of such quantities, which may serve as a reference or basis for calculation of other quantities; especially a set of quantities that serve as a reference for the calculation of positions. A horizontal datum is the set of constants specifying the coordinate system to which horizontal coordinates are referred. A vertical datum is a set of constants specifying the coordinate system to which elevations are referred. In a linear referencing system, the datum serves as the basis for locating the linear referencing system in the real world and consists of a connected set of anchor sections that have anchor points at their junctions and termini.

digital – a description of data which is stored or transmitted as a sequence of discrete symbols from a finite set; most commonly this means binary data that are processed by computers.

digital orthorectified image – a digital representation of an orthorectified image. The digital image is composed of pixels whose dimensions define the minimum unit of resolution (expressed in distance on the ground).

elevation – the vertical distance from a datum to a point or object on the Earth's surface.

feature – a real world phenomenon of a given type, such as a “road”.

Federal Geographic Data Committee – an interagency committee established by Office of Management and Budget Circular A-16 to promote the coordinated development, use, sharing, and dissemination of spatial data, and to coordinate the development of the National Spatial Data Infrastructure.

generalization – reduction in detail in geographic data representation; for example, resampling elevation or image data to a larger spacing or reducing the number of points in a line.

geodetic control – a network of geodetic control points, or a set of known reference positions, used as a basis for obtaining positions of other features.

geographic information system (GIS) – a computer system for the input, editing, storage, maintenance, management, retrieval, analysis, synthesis, and output of spatial information. In the most restrictive usage, the term refers only to hardware and software. In common usage, it also includes data, and sometimes the people and procedures involved in operations.

Global Positioning System (GPS) – a satellite-based navigation system deployed by the Department of Defense used to determine locations on the Earth's surface.

governmental units – the geographic extent of units of government, including the Nation, States, counties, incorporated places and consolidated cities, functioning and legal minor civil divisions such as towns and townships, Federal- or State-recognized American Indian reservations and trustlands, and Alaskan Native regional corporations.

hydrography – surface water features, such as streams and rivers, lakes and ponds, canals and ditches, and oceans.

integration – the processes required to compile a consistent set of data from different sources of data. In *horizontal* integration, sets of data of the same theme for adjoining areas are processed to remove gaps, overlaps, spurs, and other inconsistencies along their common edge. In *vertical* integration, sets of data of different themes for the same area are processed to ensure that, where features have the same alignments on the ground, the data that encode the features also have the same alignments. In *semantic* integration, sets of data that express a common theme or meaning in different ways are processed to express the theme or meaning in a consistent way.

line – a one-dimensional directed and nonbranching sequence of nonintersecting line segments.

linear referencing method – a mechanism for finding and stating the location of any point along a network by referencing it to a known point. Linear referencing methods consist of traversals and associated traversal reference points that together provide a set of known points, a metric, and a direction for referencing the locations of unknown points.

linear referencing system – a set of datums, networks, and linear referencing methods, whereby each point along a network can be identified uniquely by specifying the direction and distance from any known point on the network.

metadata – data about data; data about the content, quality, condition, and other characteristics of data.

National Spatial Data Infrastructure (NSDI) – the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve use of spatial data. The NSDI is an umbrella under which organizations and technology interact to foster activities for using, managing, and producing geographic data.

Federal responsibilities for the NSDI are coordinated through Office of Management and Budget Circular A-16 and Executive Order 12906.

orthorectified image – an aerial photograph or satellite image from which displacements caused by terrain relief and sensor tilt have been removed. The result combines the image characteristics of a photograph with the geometric qualities of a map.

pixel – a two-dimensional picture element that is the smallest nondivisible element of a digital image.

point – a zero-dimensional object that specifies a location.

raster data – spatial data in which locations are represented using an array of cells, pixels, or points that hold values for attributes.

reach – a continuous unbroken stretch or expanse of surface water.

reach code – a numeric code that uniquely identifies a reach.

referencing system – a set of datums and rules by which the location of points can be identified uniquely.

relief – elevations and depressions of the land or sea bottom.

resolution – the measurement of the finest detail distinguishable.

spatial data – information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth. The information may be derived from, among other things, remote sensing, mapping, and surveying technologies.

structure – something, such as a building, that is constructed.

theme – a topic or subject.

topographic map – a map that presents the horizontal and vertical positions of represented features, such elevations and depressions of the land surface (relief), water features, roads and railroads, structures, boundaries, names, and other themes.

topography – the configuration (relief) of the land service; a representation or portrayal of that configuration.

transaction – a unit of processing activity that accomplishes a specific purpose such as a retrieval, an update, a modification, or a deletion of one or more data elements.

transportation – features used to move people and goods from place to place, such as roads, trails, railroads, ports, airports, and waterways, and related features such as bridges and tunnels.

vector data – spatial data in which locations of features are represented using points, lines, and areas.

Appendix 1. The Changing Needs for Spatial Data, and Opportunities for Meeting These Needs

During the development of the concept, USGS interviewed key individuals familiar with the development and use of spatial data from Federal, State, and regional government agencies, the private sector, the academic community, and professional organizations. In addition to the interviews, the USGS reviewed a number documents listed in the References section.

The following are current and developing spatial data needs, and the implications of new capabilities, identified during the development of the report:

- *There continues to be an unmet need for a common set of basic spatial data.* The Federal Government, other public and private organizations, and individuals, need a common set of basic spatial data that they can expand and enhance to meet their mission, business, or individual needs. Not only must these data be developed, but they also must be maintained. These data would provide an enterprise level of spatial data for the Federal Government.
- *For some places, much data are available; for others, there is very little data.* For areas for which spatial data exists, the data developed by different jurisdictions are not consistent. For other areas, little data, or data of unknown or poor quality, exist. Existing data should be used as a starting point for areas for which they are available, and investment is needed where data are lacking.
- *A standing collection of basic spatial data is needed*. There is a need to develop and maintain a standing inventory of these data. In spite of improvements in remote sensing and other technologies, a capability to develop all basic spatial data "just in time" is unlikely. The need to analyze changes in the landscape through time also requires an inventory of data.
- *These data must*:
    - *Be current.* Natural and human processes change even the most "timeless" features, such as elevations, and some, such as a network of roads, can change very quickly. Data must accurately reflect the current state of the landscape. Reasons to maintain currentness range from ensuring correct results from analyses to gaining the confidence of those using the data. Continual maintenance is needed to ensure that the data typically are current in terms of days or months, not years.
    - *Be useful for any arbitrarily defined geographic area*. Public and private organizations use spatial data to meet mission and business needs, and these needs often have different "footprints" on the landscape. For example, census data follow the geographies of census and political units, work on water resource problems often follows watersheds, and responses to natural disaster follow the area affected. For the Federal Government, these areas may be as small as individual farms or fields, or as large as ecosystems (and sometimes the entire Nation). The data must have a consistent classification, and minimum criteria for completeness and

positional accuracy. Inconsistencies must be resolved among data collected over different areas or by different jurisdictions, as must inconsistencies among different themes of data.

- *Both digital and paper forms of basic spatial data are needed; paper maps should be derived from a master set of digital data*. Much as word processing and other office productivity software has not eliminated paper documents, basic spatial information in the forms of both digital data and paper maps will continue to be needed. Data portrayed on maps must be consistent with those provided in digital form, and should be derived from these digital data.

- *Technology will continue to evolve, and will provide new ways to collect, maintain, access, and use basic spatial data.* There will be few technical limitations to meeting needs for spatial data; indeed, the future promises an expanding number of possibilities for spatial data collection, maintenance, access, and use. Advances in computing hardware, and broadband and wireless communications, will provide the basic ability needed to store, process, and communicate data. The trend of including Global Positioning System and "locationally aware" technologies in cell phones and other personal electronic devices promises increased use of spatial data, and intriguing new ways of collecting and maintaining these data. Standards, including those for open geographic information technology and processing methods, will be key to capitalizing on these technologies. For the foreseeable future, it appears likely that human intervention will be required to interpret features such as roads and buildings from remotely sensed data.

- *The Internet will continue to provide new ways for disseminating and using spatial data.* The Internet will be the enabling technology that will increase the public and private sectors' and individuals' use and awareness of spatial data. Evolving from a means to view content and purchase products, the Internet will encourage the development more holistic spatial services, stand-alone devices, specialized applications, customized spatial queries, and interactive capabilities. The result of these changes will be a proliferation of specialized devices that require spatial data accessed over the Internet to operate. The business models for providing these services will result in a number of new funding models.

- *Common needs and interests offer opportunities for partnerships to collect, maintain, access, and use basic spatial data among Federal agencies, and with other public organizations, notably State and regional organizations.* While the missions of Federal agencies vary, and often are different from those of State, regional, local, and tribal governments, there are overlapping needs and interests in a common set of basic spatial data. By pooling resources, common needs can be met more quickly. The challenge of organizing these resources is substantial.

- *Private sector investments in capabilities to collect, maintain, access, and use basic spatial data, and in the development and maintenance of data, provide opportunities to meet Federal needs.* The private sector currently collects under contract basic spatial data that meet Federal specifications. Moreover, some privately held data developed and maintained for other markets could meet

Federal needs. It is worth noting, however, that some private sector business models are new and evolving, and it is too early to predict the long-term success of these approaches.

- *Volunteers may be an untapped means of maintaining basic spatial data.* With the advent of "locationally aware" capabilities in cell phones and other personal electronic devices, volunteers knowledgeable about changes in their locales could be a useful source of information needed to maintain basic spatial data.
- *The National Spatial Data Infrastructure provides the context for developing and maintaining basic spatial data.* The National Spatial Data Infrastructure provides a broad set of principles and capabilities within which these basic spatial data will evolve. The framework concept described by the Federal Geographic Data Committee provides a useful starting point.
- *Policies and other rules for accessing and sharing basic spatial data, such as licenses, must allow the data to flow as needed to meet Federal mission needs.* The Federal Government needs basic spatial data only as much as these data help meet mission needs. The trend for the Federal Government to carry out programs and evaluate results by working with State and other public entities, the private sector, nongovernmental organizations, and the public will continue to grow. Basic spatial data must be available for use by those carrying out programs, and for reuse by different combinations of organizations for follow-on work and long-term understanding of change. The ability to share data widely also increases the opportunities for partnerships to fund data collection and maintenance. Therefore, licenses and other policies for basic spatial data use must allow for data sharing among partners that carry out, monitor, or evaluate Federal activities.
- *Federal leadership and commitment is needed to ensure that basic spatial data are available to support Federal agencies in accomplishing their missions.* Without leadership, agencies are likely to expend funds in areas outside their mission responsibilities to obtain these data. A coordinated approach to developing and maintaining these data would reduce duplication and expense.
- *As the Nation's largest civilian mapping agency, it is the mission of the U.S. Geological Survey to lead the development and maintenance of this common set of basic spatial data, although a new approach is needed.* The current approach of irregular cycles of updates, and independent lines of digital data and paper maps, will not meet the needs of the Federal Government. USGS leadership and participation, such as that demonstrated in interagency data development efforts for orthorectified imagery, elevation, hydrography, land characterization, and geographic names data, are needed to foster partnerships and approaches to provide needed basic spatial data.

Appendix 2. Research and Development Needed to Support The National Map

Applied cartographic, geographic information, and general information science research and development will be required to implement *The National Map*. Using mechanisms such as cooperative research and development agreements with the private sector, grants to universities, and interdisciplinary collaborative teams, applied research and development will be conducted in the following areas:

Database Design

- Evaluation of alternative representation models with the goal of selecting a single optimal model for each theme that will support a small, defined set of applications and product requirements.
- Design of seamless data organization methods that support incremental and transactional updates.
- Exploration of variable (not multiple) resolution models.
- Understanding of how to represent and propagate uncertainty.

Database Population Strategies

- Development of data conflation techniques (similarity indicators, multi-mode approaches).
- Identification of surrogates for permanent feature identifiers, and methods for employing them.
- Identification of strategies for data integration (registration, constraints to logical inter-theme relationships).

Data Maintenance Approaches

- Development of practical transaction-based update strategies.
- Development of means for providing temporal updates.
- Development of methods to improve the resolution and accuracy with which a feature is represented.
- Development of Internet-based change notification capabilities to take advantage of a citizenry empowered with Global Positioning System and other "locationally-aware" technology.
- Development of new techniques for detecting change.

Product Generation

- Development of user-defined product generation options, including variable footprint, time-slice, resolution, reference system, feature/theme content, and representation models.

- Deployment of techniques for generalization, symbolization, name placement, overlay and transparency levels, and collar generation.
- Exploration of new format and media options, including those that support print-on-demand.
- Development of pre-defined product templates, especially those needed to support on-the-fly generation of traditional products, such as the maps of the primary topographic series.

Accessibility

- Development of interactive data access methods that comply with open geographic information technology and processing standards, as well as other Internet standards.
- Understanding of the technical aspects of data access licensing arrangements proposed by the private sector.

Related longer-term research needs include:

- Investigations of multi-dimensional data models to support integration and application of other USGS scientific data holdings with *The National Map*.
- Understanding of the application of sensor technologies now being developed, including new techniques for sensing the landscape remotely and on the ground.
- Exploration of synchronization approaches for distributed data holdings and architectures.
- Exploiting wireless devices and technology linked to the Global Positioning System for updating data.
- Understanding mappings and transforms among different data models.
- Investigations of cognition and visualization of spatial data.